Design and Manufacturing of a DTL prototype power coupler

S. Ramberger[1], P.-E. Bernaudin[2], J.-M. De Conto[3], D. Marchand[3], E. Vernay[3], M. Vretenar[1]

1) CERN, Geneva, Switzerland
2) CEA, Saclay, France
3) LPSC (UJF, CNRS/IN2P3, INPG) Grenoble

Abstract

The design and manufacturing of a 1 MW RF power coupler intended for the CERN Linac4 drift tube linac (DTL) prototype has been undertaken within the HIPPI framework. This HIPPI note summarizes the RF and thermo-mechanical design, describes the mechanical structure and reviews the results achieved at the end of this HIPPI task.

Introduction

The design and manufacturing of a 1 MW RF power coupler intended for the CERN Linac4 drift tube linac (DTL) has been undertaken within the HIPPI framework. This HIPPI note summarizes the RF and thermo-mechanical design, describes the mechanical structure and reviews the results achieved at the end of this HIPPI task.

RF Design

The RF design is based on a short circuited waveguide with a coupling iris connecting the waveguide to the accelerator cavity. The advantage of this design compared to other solutions is the ability to change the coupling constant by changing the length of the RF short circuit. The critical parameters of this design are the size of the coupling iris and the distance of the waveguide to the accelerator cavity.

The RF design has been done using HFSS simulations. In these simulations, the geometry was reduced to a half cell of the problem and the full DTL tank was accounted for by estimating the corresponding external Q value from the Q value of the full structure. The parameters have then been optimized in order to find the required Q value.

The dependency of the external Q value on the short circuit position was calculated as well as the frequency shift corresponding to a certain Q value. These parameters are required for the cavity design and the tuning of the coupler in the final installation. The power dissipation in the waveguide and the coupling iris has been estimated in two extreme cases and serves as a basis for the thermo-mechanical design.

The RF design of the DTL coupler has been done by Pierre-Emmanuel Bernaudin from CEA, Saclay [1].

Thermo-mechanical Design

Following the RF design, the cooling pipes have been dimensioned according to the heat loss distribution found for 15% duty cycle at 1 MW of RF power. The total power to be absorbed is found to be 255 W in the connecting guide and 44 W in the waveguide flange. Two cooling pipes are therefore foreseen on the connecting waveguide, another cooling pipe has to be placed in the waveguide flange, and further two cooling pipes are attached to either wide side of the wave guide. The cooling pipes have a diameter of 10 mm and provide for water cooling at a flow speed of 2 m/s corresponding to a flow of 9.4 l/min. The corresponding heat transfer coefficient is 10 kW/(m^2·K).

The waveguide, flange and connecting guide have been simulated thermo-mechanically using a finite element method (FEM) and taking the heat transfer to the water into account. The resulting stresses and deformations have been analyzed in detail including the 1 bar pressure difference due to evacuation of the coupler. The mechanical structure consists of stainless steel sheets of 6 mm thickness which are reinforced by the flanges and fins providing the required stiffness of the structure.

The base temperature of the water is set to 25º C and the maximum temperature in the connecting guide is found to be 48º C. Von Mises stresses were found to be lower than 100 MPa except in small areas of stress concentration. Deformations remain below 0.1 mm in the flange area of the connecting guide which is acceptable with respect to the Helicoflex vacuum joint requirements and below 0.3 mm on the wave-guide structure.

The thermo-mechanical design has been undertaken at the LPSC, Grenoble [2].

Construction

Based on the RF and thermo-mechanical design studies, the manufacturing drawings of the DTL coupler have been prepared. The wave-guide including a connecting flange and a short circuit plus an additional short circuit plate for tuning the coupling factor has been constructed by LPSC, Grenoble during the year 2006.

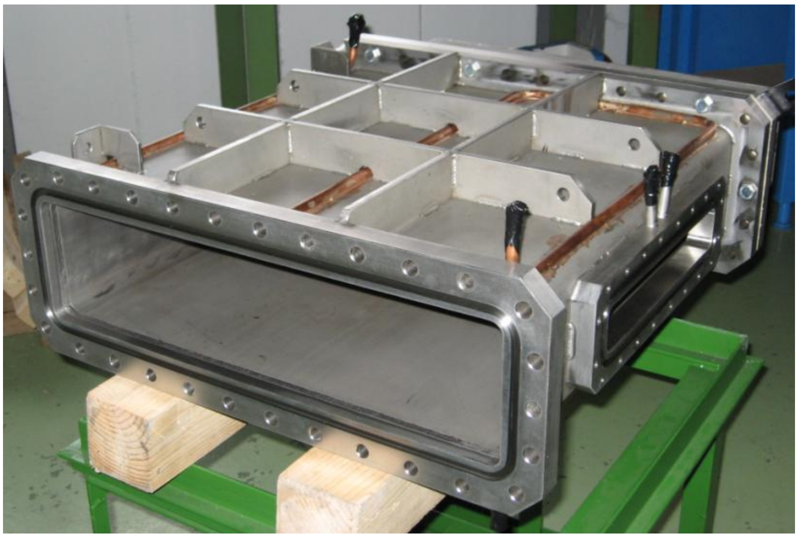


Figure 1: DTL coupler wave-guide with cooling circuits and vacuum flange sections.

Figure 1 shows the WR2300 half-height wave-guide with a vacuum flange that will be connected to the RF window providing for the vacuum to atmospheric pressure transition. On the right hand-side the flange to the connecting wave-guide section can be seen featuring a cooling circuit. At the rear end of the wave-guide structure, a short-circuit is connected to the wave guide. Fins on the broad face of the wave guide provide for the mechanical strength and rigidity that is required to stand the atmospheric pressure against the vacuum inside the wave-guide. The whole structure is assembled from stainless steel sheets of 6 mm thickness by welding. A copper cooling pipe on the broad face of the wave guide was soldered to the stainless steel wave-guide to provide for cooling.

The DTL coupler has been finished and delivered to CERN in November 2007. Tests at high RF power will take place only after delivery at CERN of the prototype drift tube linac structure being built by the Russian institute VNIIEF, which is currently delayed by about 18 months. Shortly before installation, the DTL coupler shall be copper plated.

Acknowledgements

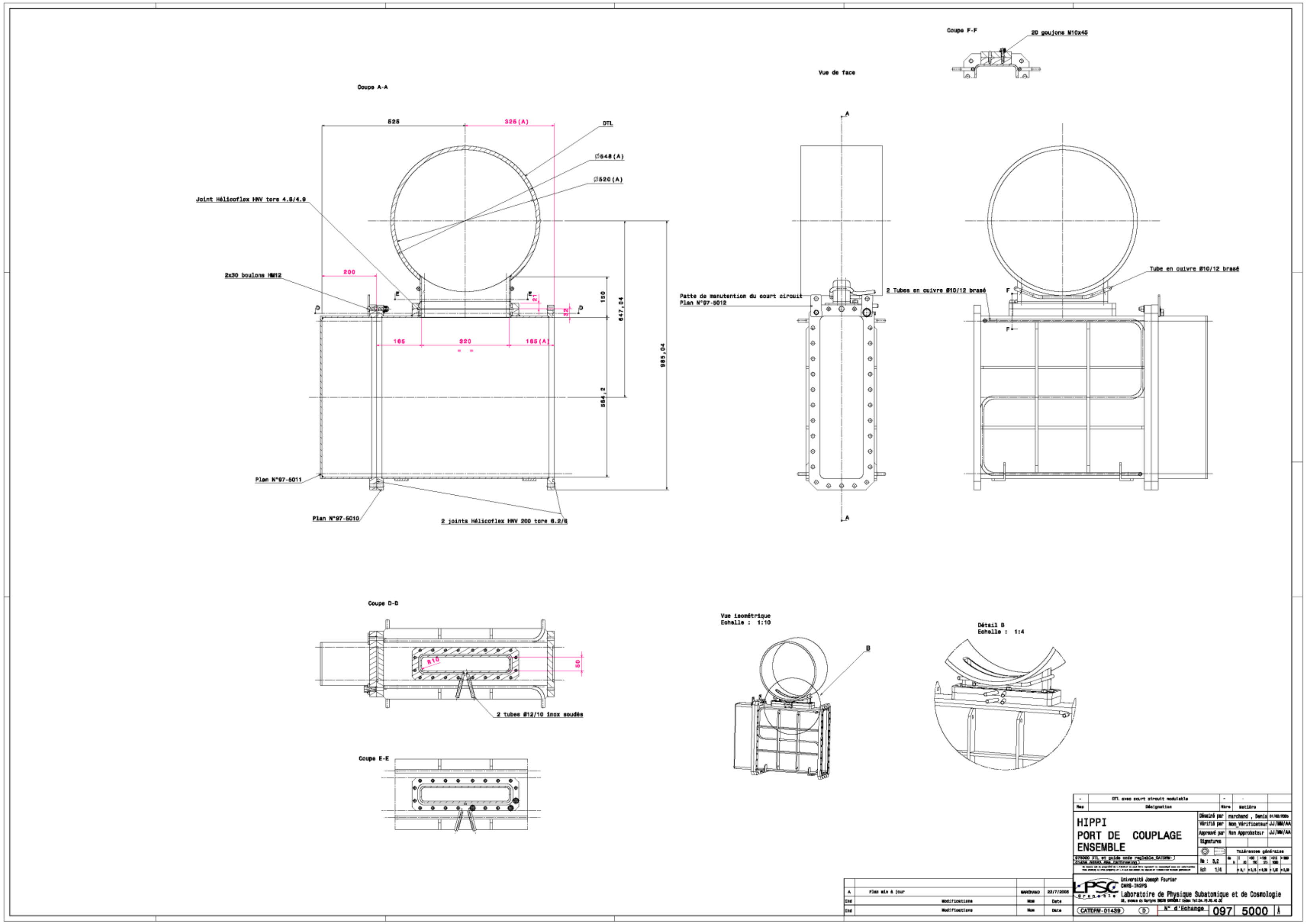
We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395)

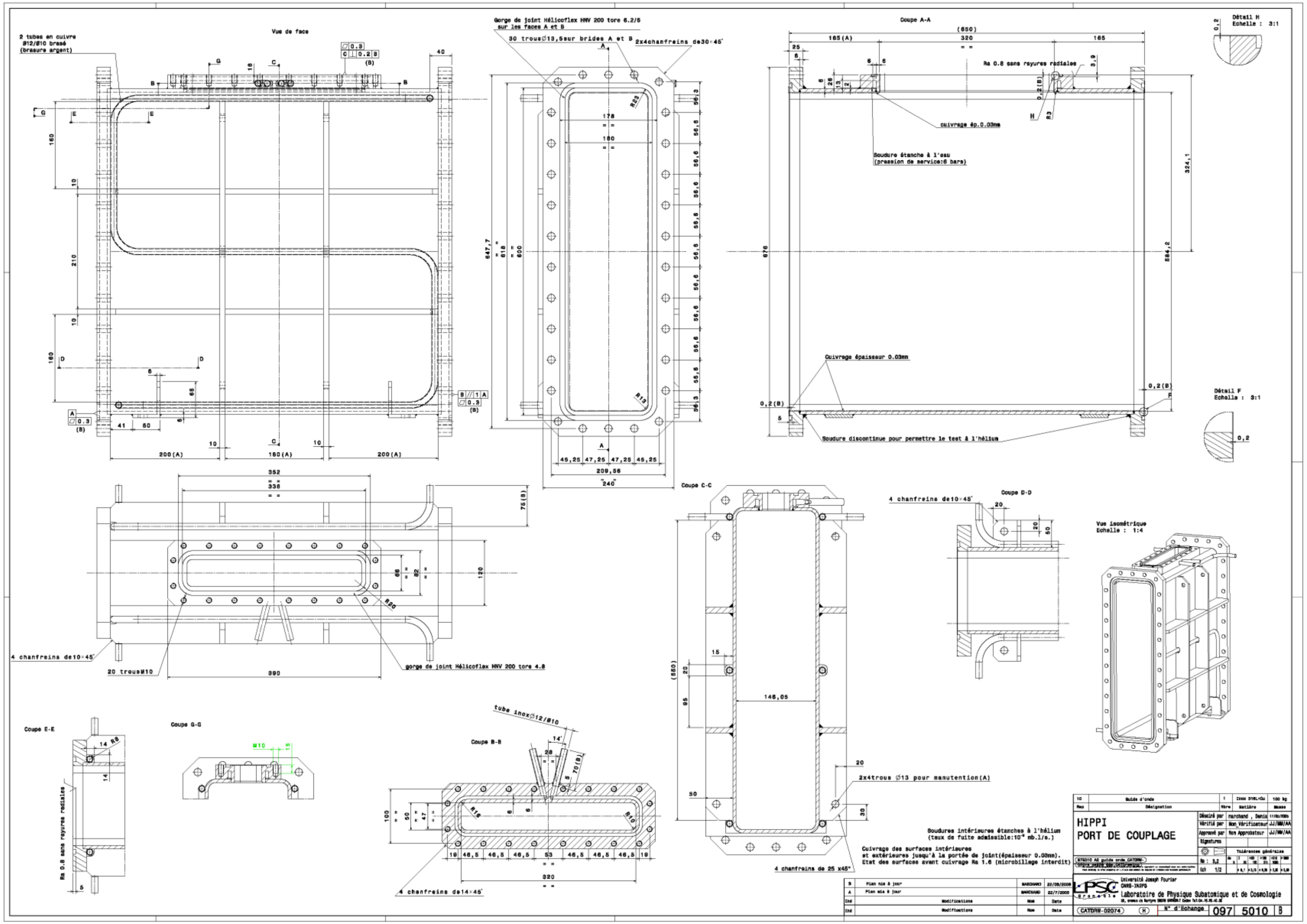
References

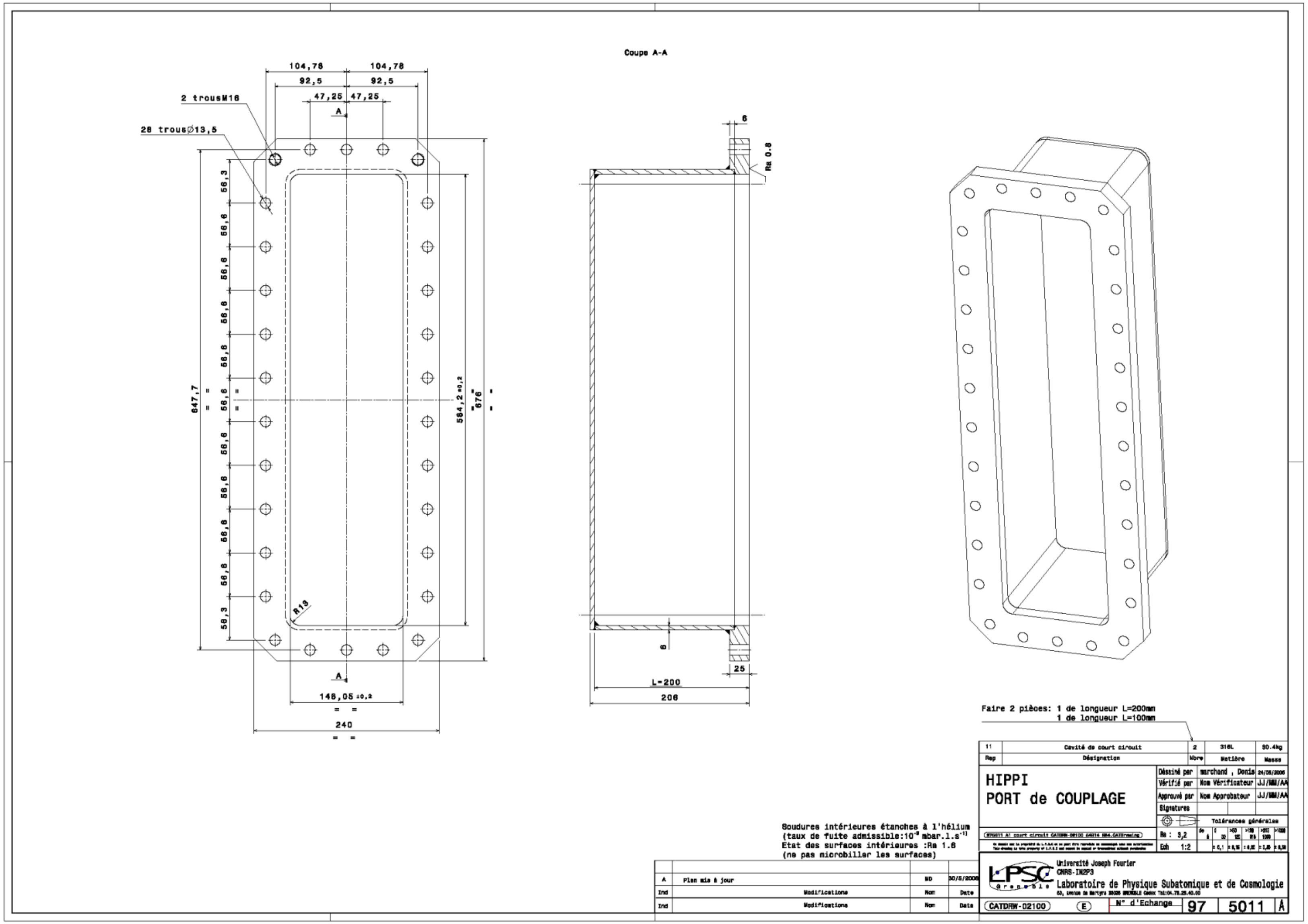
[1] P.-E. Bernaudin, “RF design of a DTL power coupler”, CARE/HIPPI Document-2005-002

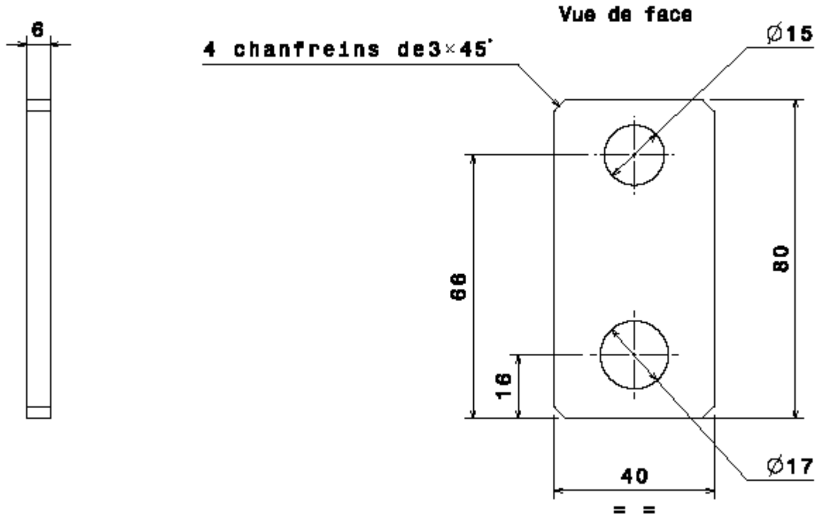
[2] E. Vernay, J.-M. De Conto, D. Bondoux, “Thermomechanical study of the HIPPI/LINAC4 DTL coupling port. Results for the ‘connecting guide’ part.”, CARE/HIPPI Document-2005-010

ANNEXES: Drawings


Coupe A-A
525
325 (A)
DTL
Ø548 (A)
Ø520 (A)
Joint Hélicoflex HNV tore 4.8/4.9
2x30 boulons HM12
200
150
647,04
985,04
554,2
165
320
165 (A)
Plan N°97-5011
Plan N°97-5010
2 joints Hélicoflex HNV 200 tore 6.2/6
Vue de face
Patte de manutention du court circuit
Plan N°97-5012
2 Tubes en cuivre Ø10/12 brasé
Tube en cuivre Ø10/12 brasé
Coupe F-F
20 goujons M10x45
Coupe D-D
R10
50
2 tubes Ø12/10 inox soudés
Coupe E-E
Vue isométrique
Echelle : 1:10
B
Détail B
Echelle : 1:4
DTL avec court circuit modulable
Rep
Désignation
Nbre
Matière
HIPPI
PORT DE COUPLAGE
ENSEMBLE
Dessiné par
marchand , Denis
Vérifié par
Nom_Vérificateur
JJ/MM/AA
Approuvé par
Nom Approbateur
JJ/MM/AA
Signatures
Tolérances générales
Ra : 3,2
Ech 1/4
Université Joseph Fourier
CNRS-IN2P3
Laboratoire de Physique Subatomique et de Cosmologie
A
Plan mis à jour
22/7/2008
Modifications
Nom
Date
CATDRW-01439
D
N° d'Echange
097
5000
A


Vue de face
Coupe A-A
Coupe C-C
Coupe D-D
Coupe E-E
Coupe G-G
Coupe B-B
Vue isométrique
Echelle : 1:4
Détail H
Echelle : 3:1
Détail F
Echelle : 3:1
HIPPI
PORT DE COUPLAGE
Laboratoire de Physique Subatomique et de Cosmologie
097 5010 B


Coupe A-A
2 trousM16
28 trous∅13,5
104,78
92,5
47,25
146,05 ±0,2
240
647,7
584,2 ±0,2
676
R13
L=200
206
25
Ra 0.8
Faire 2 pièces: 1 de longueur L=200mm
1 de longueur L=100mm
Cavité de court circuit
316L
30.4kg
HIPPI
PORT de COUPLAGE
Soudures intérieures étanches à l'hélium
(taux de fuite admissible:10⁻⁹ mbar.l.s⁻¹)
Etat des surfaces intérieures :Ra 1.6
(ne pas microbiller les surfaces)
Plan mis à jour
Modifications
Université Joseph Fourier
CNRS-IN2P3
Laboratoire de Physique Subatomique et de Cosmologie
CATDRW-02100
N° d'Echange
97
5011
A



Rep	Désignation	Nbre	Matière	Masse
12	Patte de manutention du court circuit	2	A46	0.13kg

HIPPI
PORT DE COUPLAGE
ENSEMBLE

Déssiné par	vezzu	29/07/2005
Vérifié par	Nom Vérificateur	JJ/MM/AA
Approuvé par	Nom Approbateur	JJ/MM/AA
Signatures		

975012 A5 patte manutention court circuit CATDRW-02731 25785 484.CATDrawing

Tolérances générales

Ra : 3,2	de à	0 30	>30 120	>120 315	>315 1000	>1000
Ech 1:1		± 0,1	± 0,15	± 0,20	± 0,30	± 0,50

Université Joseph Fourier
CNRS-IN2P3
Laboratoire de Physique Subatomique et de Cosmologie
53, avenue de Martyrs 38026 GRENOBLE Cedex Tel:04.76.28.40.00

CATDRW-02731 (A) N° d'Echange 97 5012 ..

Ind	Modifications	Nom	Date
Ind	Modifications	Nom	Date


596,2
158
R19
6
19
Fond du court circuit
1
316L
4.4kg
Rep
Désignation
Nbre
Matière
Masse
HIPPI
PORT de COUPLAGE
Déssiné par
marchand , Denis
24/03/2008
Vérifié par
Nom Vérificateur
JJ/MM/AA
Approuvé par
Nom Approbateur
JJ/MM/AA
Signatures
Tolérances générales
Ra : 3,2
Ech 1:1
Université Joseph Fourier
CNRS-IN2P3
Laboratoire de Physique Subatomique et de Cosmologie
Ind
Modifications
Nom
Date
CATDRW-03781
A
N° d'Echange
97
5013
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20-11-2006 10:46 DE A 0476284143 P.01

Le Soudage
De Précision
Grenoblois

ZA Pré Millet - 360 av. Aristide Berges
BP 14 Montbonnot St Martin
38331 SAINT ISMIER CEDEX
☎ : 04 76 52 41 55 - Fax : 04 76 52 41 01

N° 10

CERTIFICAT DE TEST D'ETANCHEITE A L'HELIUM

Date : 16/11/2006 **Commande LSPC**

Client S M G O P 5 rue P Valerien Perrin ZI La Tuilerie 381701 SEYSSINET-PARISET

Détection : global – **au jet**

Signal de tolérance : 1.10-10 Atm.cm3/s.He

Désignation	N° Plan	Résultats obtenus	Observations
Port de couplage		3.10-9 Atm.cm 3/sec	BON

Détecteur : **Type Alcatel ASM 62** **Contrôleur : Yves MEYRIEUX-BOURG**

Valeur de la fuite étalon : **1-10-7 Atm.cm3/sec ±10%**

TOTAL PAGE(S) 01